AUGUST 2021
SEVERN TRENT WATER

A6S13263 CROWLE, STW

GROUND INVESTIGATION REPORT

COWI

AUGUST 2021
SEVERN TRENT WATER

A6S13263 CROWLE, STW

GROUND INVESTIGATION REPORT

ADDRESS COWI UK Limited
Kelvin House
RTC Business Park
London Road
Derby
DE24 8UP

TEL +44 1332 343 800
WWW cowiuk.com

PROJECT NO.	DOCUMENT NO.
A131380-026	R-001

VERSION	DATE OF ISSUE	DESCRIPTION	PREPARED	CHECKED	APPROVED
1.0	AUGUST 2021	DRAFT	SYJZ	[redacted]	[redacted]

REVISION HISTORY

Revision	Description of change	Date
1.0	DRAFT FOR COMMENT	13/08/21

CONTENTS

1	EXECUTIVE SUMMARY	1
2	INTRODUCTION	2
2.1	Scope and Objective of the Report	2
2.2	Description of the Project	2
2.3	Geotechnical Category of Project	2
3	SITE LOCATION AND DESCRIPTION	3
3.1	Site Location	3
3.2	Site Description	4
3.3	Topographical Maps	4
3.4	Geological Maps and Memoirs	4
3.5	Records of Mines and Mineral Deposits	7
3.6	Environmental Designations and Archaeology	7
3.7	Existing Ground Investigation Information	7
3.8	Flood Records and Hydrology	8
3.9	Contaminated Land	8
3.10	Unexploded Ordnance	8
4	GROUND INVESTIGATION	9
4.1	Field Work	9
4.2	Laboratory Testing	10
5	GROUND CONDITIONS	11
5.1	Rising Main Replacement	11
5.2	Crowle STW Treatment Works Infrastructure Replacement	23
6	Geotechnical Design Parameters	28
6.1	Rising Main Replacement	28
6.2	Crowle STW Treatment Works Replacement	29
6.3	Ground Chemistry and Buried Concrete Classification	30
7	GEOTECHNICAL RISKS	31
8	CONCLUSIONS	32
8.1	General Site Conditions	32
9	REFERENCES	33

APPENDICES

Appendix A : Drawings

Appendix B : Ground Investigation Factual Report

TABLES

Table 2-1: List of the drawings 2
Table 5-1: Typical Bulk Density Values (BS8002:2015 Code of Practice for Earth Retaining Structures) 13
Table 5-2: Summary of PSD test results of granular alluvium 13
Table 5-3: Summary of PSD test results of cohesive alluvium 13
Table 5-4: Summary of plasticity test results 14
Table 5-6: Strength classification for Rock (BS5930:2015) 18
Table 5-7: Groundwater Monitoring Summary – (made ground and alluvium) 20
Table 5-8: Groundwater Inflow Summary of the MMG 20
Table 5-9: Ground gas Summary (* > than the % LEL.) 21
Table 5-10: Ground Model for the rising main section within the STW Works. 22
Table 5-11: Ground model for the extent of the rising main within the fields off Windsor Crescent and adjacent to the STW treatment works. 22
Table 5-12: Summary of PSD test results for the cohesive alluvium 24
Table 5-13: *Summary of PSD test results for the granular alluvium* 24
Table 5-14: Summary of Plasticity test results of organic soils 24
Table 5-15: Summary of Plasticity test results (cohesive soils) 25
Table 5-16: Ground model for STW Treatment Works Replacement. 27
Table 6-1: Summary of Geotechnical Parameters for – Rising main 28
Table 6-2: Summary of Geotechnical Parameters for Crowle STW 29

FIGURES

Figure 3-1: Location Map 3
Figure 3-2: Superficial Geology 5
Figure 3-3: Bedrock Geology 6
Figure 5-1:Plasticity Index against Liquid Limit for Alluvium 14
Figure 5-2: SPT N_{60} values in Alluvium 15
Figure 5-3: Shear Strength Vs Depth in Alluvium for boreholes BH03, BH04 and BH05 16
Figure 5-4: Plots of Plasticity Index against Liquid Limit for alluvium 25
Figure 5-5: SPT N_{60} values in Alluvium 26

1 EXECUTIVE SUMMARY

COWI UK Limited (COWI) has been appointed by Severn Trent Water Limited (STW) to prepare a Ground Investigation Report (GIR) to inform the design of the new infrastructure proposed to increase the capacity of the existing sewage treatment works (STW) on Marsh Road and all additional works proposed to replace an existing rising main, extending from the existing STW on Marsh Road to to the existing pumping station off Windsor Crescent, Crowle, Lincolnshire.

Two separate ground investigations (GIs) were carried out to develop ground models and provide engineering soil parameters to inform the design of these two projects. The ground investigations also determined the groundwater and topographical levels at the exploratory hole locations.

The ground investigation scope for the STW was designed and prepared by [redacted].

The additional ground investigation works for the rising main route and subsequent laboratory testing was designed and prepared by COWI UK.

The ground investigation works at the sites were completed by Nicholls Colton Group between March and April 2021 and together they included the following overall works:

- 5 No. boreholes using a combination drilling rig utilising window sampling followed by rotary core to a maximum depth of 20m bgl.
- 5 No. cable percussive boreholes to a maximum depth of 10m bgl.
- 3 No. machine excavated trial pits to depths between 2.50 and 3.00m bgl.
- In situ testing (Standard Penetration Tests)
- Insatllation of 9 No. gas and groundwater monitoring standpipes.
- Laboratory testing of samples recovered.

The findings of these GIs were supplemented by historic GI data provided by the British Geological Survey (BGS) and other freely available sources.

The results of the two ground investigations have been combined into this one report. The data including all the exploratory hole logs, in situ test results and subsequent laboratory testing results have been used to derive the ground models, with AOD levels, thicknesses and descriptions of the strata adopted.

Ground conditions at the sites generally comprise varied made ground overlying peat, alluvium (silty sand and silty clay), in turn overlying Mercia Mudstone Group (MMG) deposits of soft, silty clay (completely weathered mudstone) and extremely weak mudstone, interbedded with siltstone and occasional gypsum veins.

DRAFT

2 INTRODUCTION

2.1 Scope and Objective of the Report

COWI UK Limited (COWI) has been appointed by Severn Trent Water Limited (STW) to prepare a Ground Investigation Report (GIR) to inform the design of the new infrastructure proposed to increase the capacity of the existing sewage treatment works (STW) on Marsh Road and all additional works proposed to replace an existing rising main, extending from the existing STW on Marsh Road to to the existing pumping station off Windsor Crescent, Crowle, Lincolnshire.

The objectives of this Ground Investigation Report (GIR) are:

- Interpretation of ground investigation data to present ground models with geotechnical design parameters

This report has been prepared in accordance with British Standard BS EN 1997-1:2004+A1:2013 Eurocode 7 – Geotechnical Design - General Rules, the GIR summarises the ground investigation site works and subsequent laboratory testing, collating the information obtained to present a ground model with geotechnical parameters derived from material descriptions, in situ and laboratory testing.

2.2 Description of the Project

Severn Trent Water Limited aims to replace:

- The existing rising main extending across farmland from Crowle STW to the existing pumping station off Windsor Crescent to the southeast.
- The majority of the existing STW with new infrastructure located within the north-west corner of the STW site and within the adjacent field, to the west, which is currently privately owned.

List of Drawings
A7S13262-PFC-XX-ZZ-DR-C-0003_S1_P01.02-DRAFT
A7S13263-STW-ZZ-XX-DR-C-0002-P01.01

Table 2-1: List of the drawings

2.3 Geotechnical Category of Project

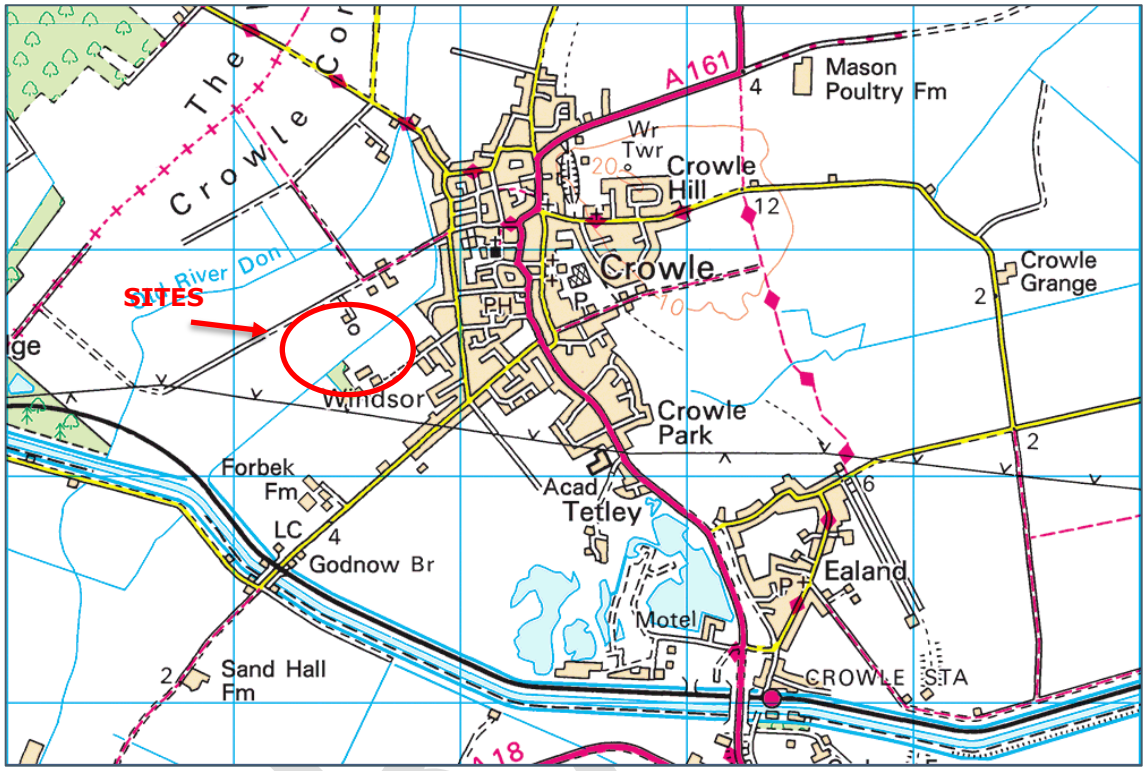
It is considered that this scheme will fall into a Geotechnical Category 1 as defined in BS EN 1997 Eurocode 7 (i.e. projects that include relatively simple structures, earthworks or geotechnical activities for which it is possible to ensure that the fundamental requirements will be satisfied on the basis of experience and qualitative geotechnical investigations, with negligible risk in terms of overall stability, ground movements and known ground conditions).

DRAFT

3 SITE LOCATION AND DESCRIPTION

3.1 Site Location

The sites are located west of the village of Crowle, Lincolnshire, approximately 11km west of Scunthorpe. The National Grid Reference for the STW is SE 77062 12342.



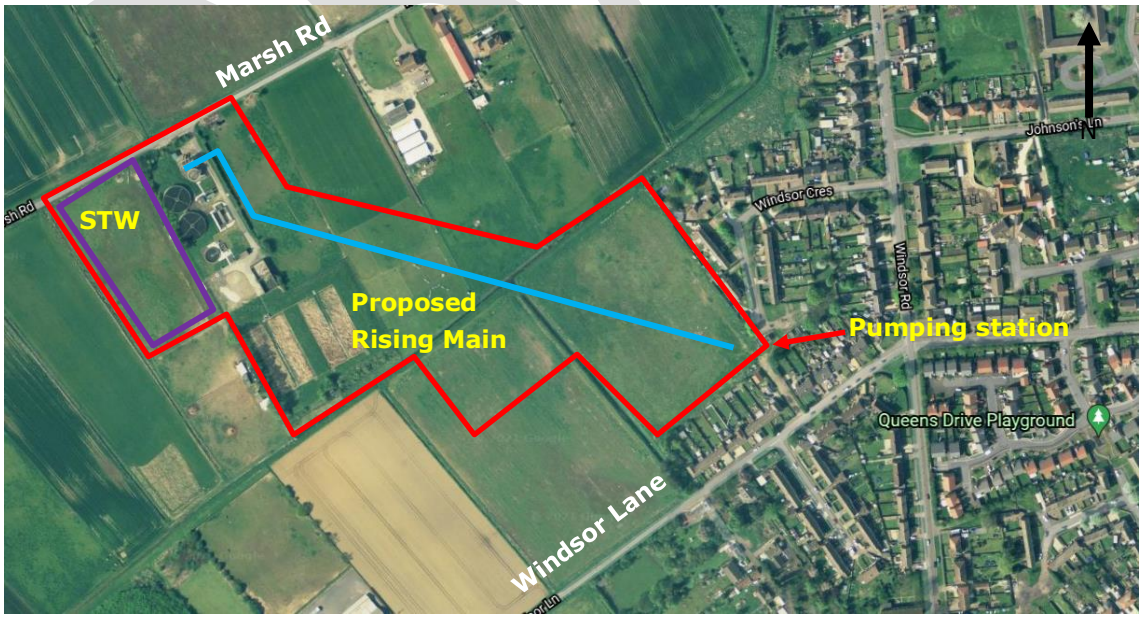


Figure 3-1: Location Map

3.2 Site Description

The existing rising main route and the STW site are shown on Figure 3-1. The rising main extends from a pumping station off Windsor Crescent, through farm land to the west of the town, north west towards Crowle STW treatment works on Marsh Road. The new STW infrastructure will be sited to the west of the existing STW. The exact location is shown in Drawing Number A4S/01456-CUL-ZZ-XX-DR-C-010 A01: Proposed Sewer Plan Long Section Sheet 1 of 2.

3.3 Topographical Maps

3.3.1 Current Topography

The general area of the site is elatively flat lying with ground levels between approximately 1.9mAOD and 2.5mAOD, based on ground elevations recorded at the exploratory hole locations.

3.3.2 Historic Mapping

The purpose of this section is to identify any previous land use and history, which has the potential to result in ground-based risk.

The available historical maps date back to 1885 at the earliest. At this time the sites comprised the existing a road (Marsh Road) and agricultural fields in the northern area, with the surrounding land occupied predoiminantly by agricultural fields and farm buildings.

The 1943 map shows no significant change to the sites. Several residential properties are shown directly north of the sites and immediately to the the east. No significant change is shown on the sites until 1956 with the identification of the sewage treatment works.

Generally, there is an insignificant change in the use of the sites between 1973 and 2008, except for continuous development of the surrounding residential areas.

3.4 Geological Maps and Memoirs

The following sources of information were used to provide information on the geology:

- 1:50,000 scale BGS Map Sheet 79 for Goole, 1972.
- British Geological Survey (BGS) online GeoIndex geology map viewer
- Magic Interactive Map viewer

DRAFT

3.4.1 Superficial Geology

The published BGS mapping indicates the sites to be underlain by alluvium and the Sutton Sand Formation (SUTN) of Quaternary age. Peat deposits are shown to be present to the southwest also.

The Sutton Sand Formation is generally described as fine-grained, silty sand. The alluvium is described as clay, silt, sand and gravel. The clay is usually soft to firm, consolidated, compressible and silty, but can contain layers of silt, sand, gravel and peat.

The superficial geology in the area of the sites obtained from the BGS GeoIndex is shown in Figure 3-2 below.

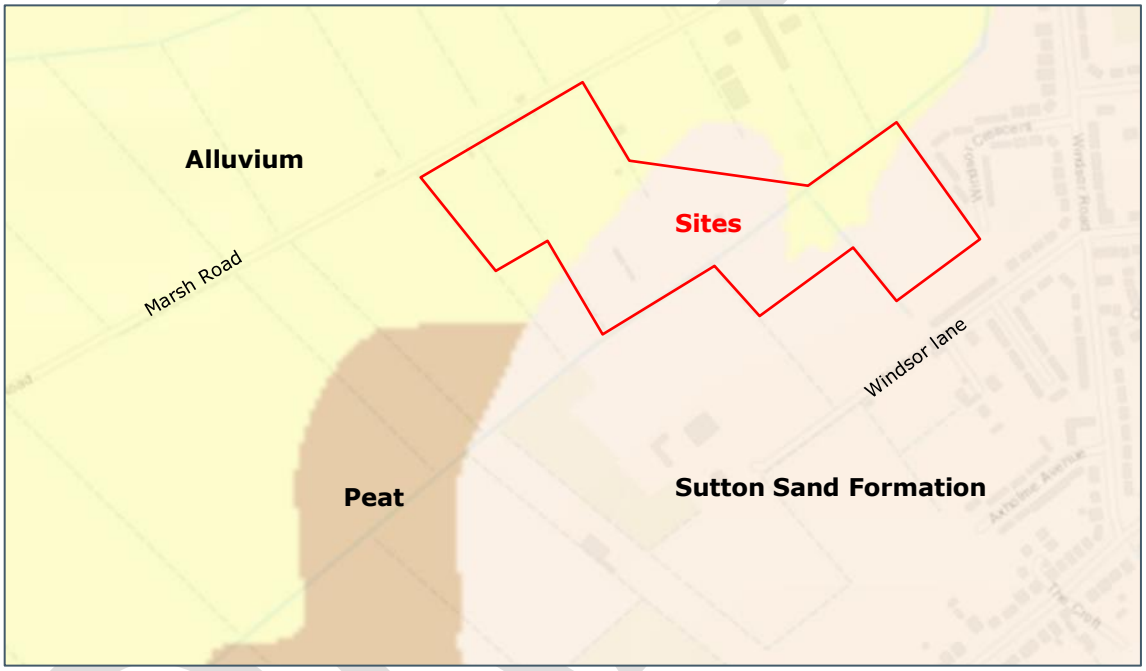


Figure 3-2: Superficial Geology

3.4.2 Bedrock Geology

BGS records indicate that the bedrock geology comprises the Mercia Mudstone Group (MMG) of Triassic age. The Mercia Mudstone typically comprises red-brown, fractured mudstone and silty mudstones that weather to calcareous clay or marl, with subordinate siltstones and halite bearing units; greenish-grey mudstones and grey mottling are common, siltstones less so.

The solid geology in the site area obtained from the BGS GeoIndex is shown in .

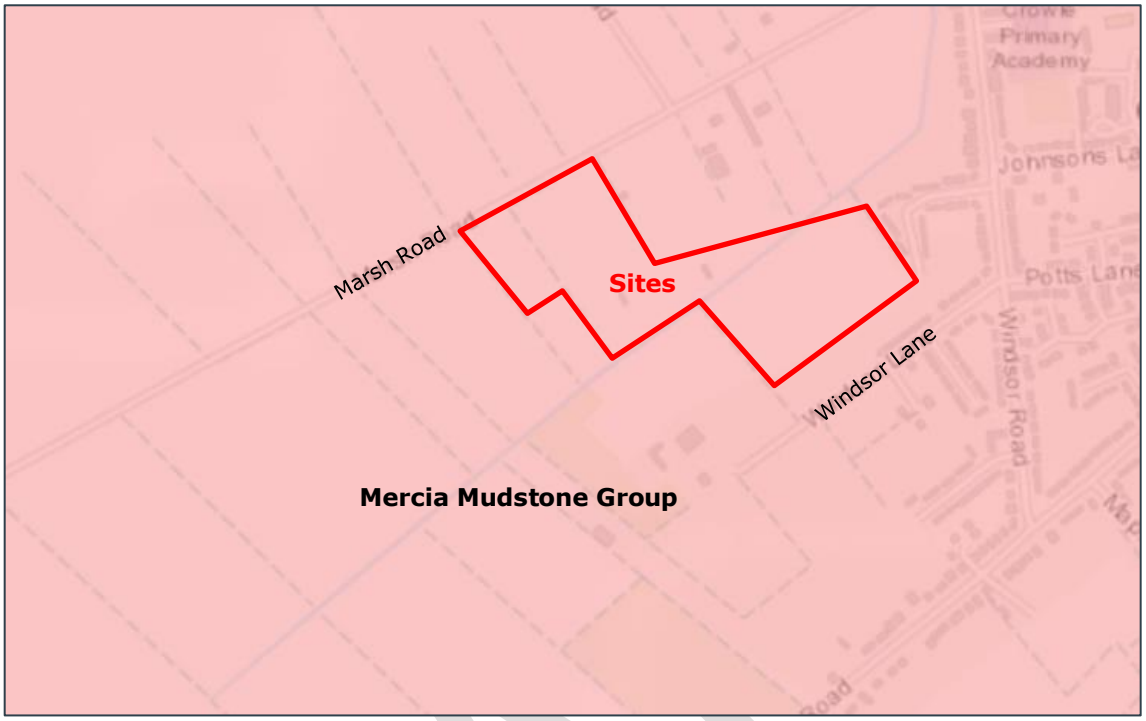


Figure 3-3: Bedrock Geology

3.4.3 Hydrogeology

Aquifer Designation

The Environment Agency (EA) classifies the Sutton Sand Formation and the alluvium as Secondary A Aquifers, defined as permeable layers capable of supporting water supplies at a local rather than strategic scale and in some cases forming an important source of base flow to rivers, these are general aquifers formerly classified as minor aquifers.

The Mercia Mudstone is classified as a Secondary B aquifer, predominantly lower permeability layers which may store/yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.

Groundwater Source Protection Zones

Groundwater Source Protection Zones (SPZs) are defined by the EA for groundwater sources such as wells, boreholes and springs that are used for public drinking water supply. SPZs show the level of risk of contamination from activities on or in the ground that have the potential to cause groundwater pollution in the area and affect water quality at an abstraction. The pollution threat depends on whether the activity is located within the catchment of the groundwater source and on the travel time to the abstraction point. The risk posed by a particular activity to a groundwater source depends on its proximity. Travel time of potential pollutants is defined as an estimation of the time it would take for a pollutant which enters the saturated zone in an aquifer to reach the abstraction point.

The EA identifies the site area as not being within any SPZ, but the site does lie within a Medium - High Groundwater Vulnerability Risk area, being an area able to transmit pollution to groundwater, characterised by high-leaching soils and the absence of low-permeability superficial deposits.

The EA may set restrictions to some types of development that may not be appropriate due to the risk they pose to the water environment. Such development types include, for example, land uses proposed for power generation, new combustion plants, composting facilities, incineration plants & intensive pig and poultry farming.

The proposed developments do not change the use of the site and are unlikely to constitute a risk to the groundwater source. However, advice should be sought from the Environment Agency to confirm that there are no restrictions on the development.

3.5 Records of Mines and Mineral Deposits

The site lies within the Coal Authority (CA) Coal Mine Reporting Area. Although the site lies within the reporting area, there are no known past or current mine working or entries within the vicinity of the site.

The BGS GeoIndex indicates that there are no active mines or quarries within 500m of the site.

3.6 Environmental Designations and Archaeology

There are no records of environmentally sensitive sites within the area. However, a review of the DEFRA Magic Map and the BGS GeoIndex Interactive viewers has been undertaken, which reveals the following ecological land designations:

- The site and/or the surrounding area is a habitat for corn bunting, grey partridge, lapwing, tree sparrow, turtle dove, and the yellow wagtail.
- The site/and or surrounding area is classified as Arable Assemblage Farmland Birds grade 6 (6 species present), and Grassland Assemblage Farmland Birds grade 2 (2 species present).

Furthermore, the Magic interactive viewer indicates that multiple monuments/listed buildings are within 500m of the site.

3.7 Existing Ground Investigation Information

The BGS GeoIndex was reviewed to collate previous recent and historic boreholes completed in the site area, which together with the recent GIs are used to develop the ground model as part of this Ground Investigation Report (GIR).

Six boreholes were completed in the area approximately 500m to the north west and west of the site locations. These boreholes generally indicated 0.70m to 0.80m of made ground underlain by approximately 2.3m to 2.6m of coarse/medium yellow brown sand and brown

DRAFT

silty sand (alluvium), overlying firm to stiff clay of the Mercia Mudstone Group from approximately 3.00m bgl.

3.8 Flood Records and Hydrology

According to the Environment Agency (EA), the site area lies within a Flood Zone 3- an area that benefits from flood defences: Land and property in this flood zone would have a high probability of flooding without the local flood defences.

3.9 Contaminated Land

There are no records of historical landfill, local authority, BGS or EA resgitered sites within 250m of the site.

3.10 Unexploded Ordnance

The Zetica online unexploded bomb risk maps identify the area of the site as a Low-risk area, indicating that the area has 15 bombs or less per 1000 acres.

It is considered that the site presently has a Low UXO hazard level due to the developed infrastructure in the area.

DRAFT

4 GROUND INVESTIGATION

4.1 Field Work

4.1.1 Description of Fieldwork

Nicholls Colton Group (NCG) carried out the GI works during March and April 2021. The ground investigation was divided into two separate ground investigations and comprised the following work:

Rising Main

- 5 No. boreholes using a combination drilling rig utilising window sampling followed by rotary coring to a maximum depth of 20m bgl.
- 6 No. trial pits to depths between 0.70m and 1.60m bgl.
- In situ testing (Standard Penetration Tests)
- Four standpipe installations.
- One falling head permeability test.
- Laboratory testing of samples recovered.

Crowle STW

- 5 No. cable percussive boreholes to a maximum depth of 10m bgl.
- 7 No. trial pits to depths between 3.50m and 3.70m bgl.
- In situ testing (Standard Penetration Tests)
- Five standpipe installations.
- Laboratory testing of samples recovered.

4.1.2 Factual Ground Investigation Reports

The Nicholls Colton Ground Investigations were reported in two separate factual reports:

- The proposed replacement of an existing rising main extending from Crowle STW to Windsor Crescent, Crowle, Lincolnshire – Report Number: G21013-FR
- Crowle STW replacement or refurbishment- Report Number: G21014-FR

Both reports include all exploratory hole logs, in situ and laboratory results, and are included in Appendix B.

DRAFT

4.2 Laboratory Testing

Geotechnical laboratory testing carried out across both sites included the following tests:

- Natural moisture content and Atterberg limits / plasticity.
- Particle size distribution (PSD).
- (BRE SD1) Sulphate suite.
- Unconsolidated undrained triaxial tests.
- Uniaxial compressive strength (UCS)
- Cerchar abrasivity (CA)

DRAFT

5 GROUND CONDITIONS

5.1 Rising Main

5.1.1 General

The generalised succession of deposits encountered in the exploratory holes is summarised as follows:

- Topsoil
- Made ground
- Concrete
- Alluvium
- Mercia Mudstone Group (Bedrock)

The ground investigation to inform the rising main replacement was prepared and designed by COWI UK, who also specified the laboratory testing.

5.1.2 Topsoil

Topsoil was encountered in exploratory holes BH03, BH04 and BH05 to a maximum depth of 0.10m. No description of the material was included in the borehole log and the stratum was not considered for in situ or laboratory testing.

5.1.3 Made ground

Made ground was encountered in exploratory holes BH01 and BH02 located within the existing Crowle treatment works (STW). The made ground was encountered to a maximum depth of 1.50m bgl. Concrete was encountered at the base of the made ground in both boreholes with a maximum thickness of 0.30m. Greater thicknesses of made ground are likely to be present towards the south of the treatment works due to the existing raised dessication beds and water treatment tanks.

The 1.50m thick made ground material varies in composition and includes medium to coarse, angular to rounded flint and quartz gravel (shingle dressing) and soft, locally firm, dark brown slightly sandy silty clay.

DRAFT

Ground levels within the STW treatment works vary between 1.98m AOD and 2.25m AOD across the southern section of treatment works, based on the ground levels at the exploratory hole locations. In the fields between the STW and Windsor Crescent the ground levels vary between 1.10m AOD and 2.07m AOD.

5.1.4 Alluvium

Alluvium was encountered in each of the exploratory holes, between 0.10m bgl and to a maximum depth of 14.70m bgl (-12.45m AOD) in BH02. The alluvial material generally comprised clay, silt and sand some of which was organic. The consistency of the clay encountered within exploratory holes BH01 and BH02 was very soft. The consintency of the clay encountered within boreholes BH03, BH04 and BH05 which were located away from the sewage treatment works was generally firm becoming stiff with depth. The silt and sand was encountered in a medium dense condition.

The sand and silt deposits also included considerable pockets of peat, which were reported in BH01 within the STW site and included frequent organic matter, wood fragments and root obstructions.

The alluvium in this area is recorded by the *Goole, Doncaster and the Isle of Axhome: Memoir for one-inch sheets 79 and 88 (England and Wales). 1994,* to be up to 20m thick in the deeper part of the former river channels and consisting predominantly of sand and silt.

5.1.4.1 Bulk Density

One result is available from the laboratory testing carried out. The sample was recovered from BH05 between the depths of 6.50m and 6.95m bgl and indicated an average bulk density of 19.6kN/m³ for the cohesive deposits. This result falls within the typical values for firm clay, as indicated in BS8002:2015 Code of Practice for Earth Retaining Structures (Table 5-1). No tests results are available for the granular deposits.

DRAFT

Material	Moist Bulk Density (kN/m³)	Saturated Bulk Density (kN/m³)
Soft Clay	15.0 – 19.0	15.0 – 19.0
Firm Clay	16.0 – 20.0	16.0 – 20.0
Stiff Clay	18.0 – 22.0	18.0 – 22.0
Gravel *(Loose to Dense)*	16.0 -21.0	18.0 – 23.0
Sand *(Loose to Dense)*	16.0 – 19.0	18.0 – 22.0
Silt	16.0 – 21.0	18.0 -22.0

Table 5-1: Typical Bulk Density Values (BS8002:2015 Code of Practice for Earth Retaining Structures)

Values of 19kN/m³ for the moist and saturated bulk densities of the cohesive alluvial deposits should be adopted for the design. With 18kN/m³ adopted for the moist and 20kN/m³ for the saturated bulk density for the granular deposits.

5.1.4.2 Particle Size Distribution (PSD)

Twelve PSD tests by wet sieving and sedimentation methods were undertaken on the alluvial deposits. The component proportions of the cohesive and granular materials are summarised in Table 5-2 and Table 5-3

Stratum	Range of Particle Sizes (%)		
	Fines	Sand	Gravel
Alluvium (G)	11 - 45	20 - 89	36 - 65

Table 5-2: Summary of PSD test results of granular alluvium

Stratum	Range of Particle Sizes (%)			
	Clay	Silt	Sand	Gravel
Alluvium (C)	19 - 33	66 - 79	1 - 3	1

Table 5-3: Summary of PSD test results of cohesive alluvium

5.1.4.3 Atterberg Limits / Plasticity

Fifteen tests were completed on the cohesive samples recovered from all five boreholes, the alluvium samples were recovered from depths between 2.00m bgl and 10.50m bgl. The results of these tests are summarized in Table 5-4.

Parameter	Range
Moisture Content (%)	14 - 100
Liquid Limit (%)	23 - 140
Plastic Limit (%)	18 - 78
Plasticity Index (%)	5 - 64

Table 5-4: Summary of plasticity test results

The material (not including the peat) classifies as intermediate plasticity clay, one outlier sample classified as extremely high plastic silt as shown in Figure 5-1.

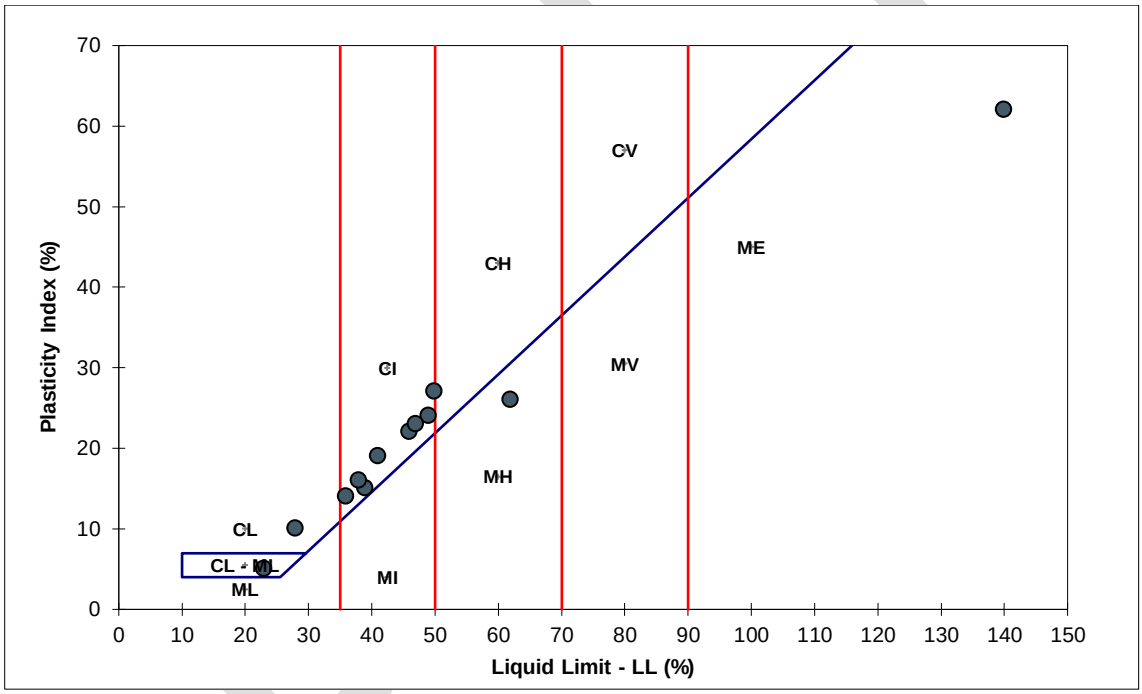


Figure 5-1:Plasticity Index against Liquid Limit for Alluvium

5.1.4.4 Standard Penetration Tests (SPTs)

Twenty five SPTs were carried out in all alluvial strata identified in all boreholes, at depths between 1.20m and 10.00m bgl, with 'N_{60}' values raging from 1 to 36. The variation of the SPT values of these depostis with depth is indicated by the SPT vs depth plot shown in Figure 5-2.

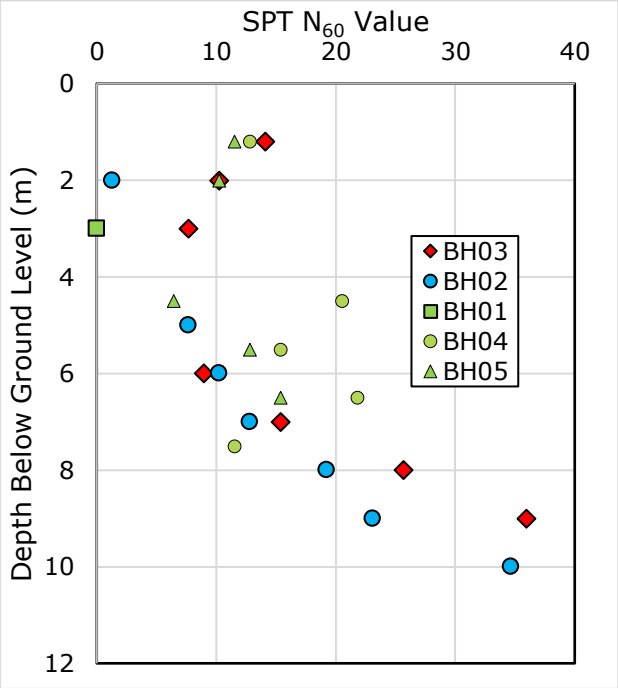


Figure 5-2: SPT N_{60} values in Alluvium

**N values corrected for hammer efficiency only, not corrected for overburden*

The general trend of the SPT results carried out in all boreholes indicate an increase in strength with depth as would be expected. The two outlier values of 0 and 1 at 2.00m and 3.00m bgl are the highly compressible organic soils.

The results carried out within the cohesive soils indicate a range in values between 6 and 23, these soils were encountered at depths between 4.50m and 9.00m bgl. The higher SPT values encountered below a depth of 8.00m bgl were obtained from the granular medium- dense sand encountered in boreholes BH03 and BH02.

5.1.4.5 Shear Strength

One unconsolidated undrained trialxial test was undertaken on a sample retrieved from the alluvium at a depth of 6.50m bgl. The test revealed an undrained shear strength (Cu) of 41kPa, which equates to a low medium strength in accordance with EC7.

The exploratory hole logs describe the cohesive material as very soft to firm consistency. SPT 'N' values can be used to derive shear strength values in cohesive soils adopting a multiplying factor of 4.5 for clay (as suggested by Stroud, 1975 & CIRIA, 570); corrected SPT 'N_{60}' values in the cohesive soil range between 1 and 23 indicating Cu values ranging from 6kPa to 104kPa, which equates to low to high strength clay.

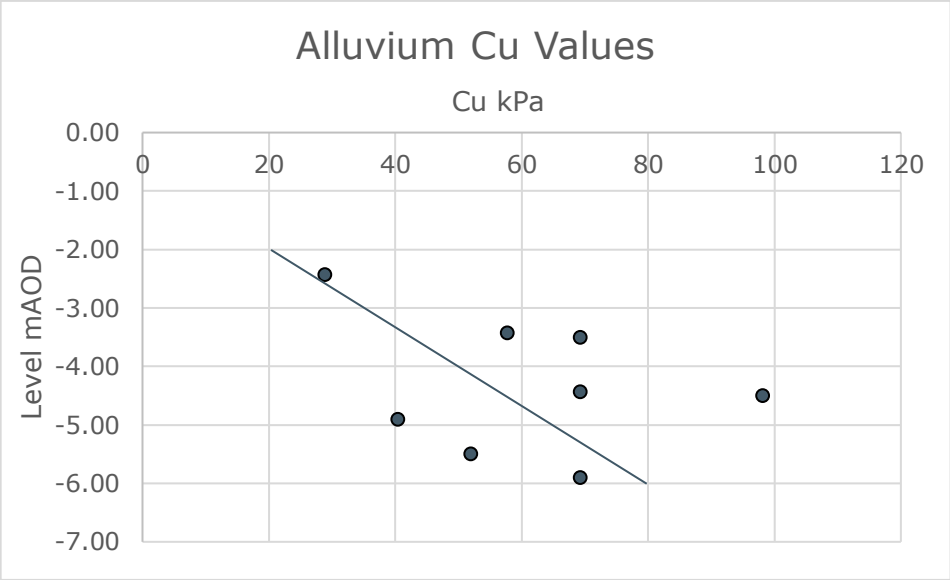


Figure 5-3: Shear Strength Vs Depth in Alluvium for boreholes BH03, BH04 and BH05

The result indicated by the SPTs are wide ranging but there is a slight increase in strength with depth, as would be expected. Therefore, a design line of CU=29 + 15z kPa, where z = 0 at -2.00m AOD is recommended for design purposes in the area covered by boreholes BH03, BH04 and BH05(Figure 5-3). The clay encountered in boreholes BH01 and BH02 is very soft and soft with SPT N values of 0 near surface and correlated Cu values of 45kPa at a depth of 7.00m bgl.

For the granular material a constant volume angle of friction of 34 degrees is recommended for design purposes, based on SPTs, PSD results and guidance in BS 8002:2015.

5.1.4.6 Stiffness

The undrained stiffness (Eu) of a cohesive soil can be derived from the strength (Cu) (Jamiolkowski et al.1979). Based on the plasticity index values (PI <30%), an Eu/Cu value of 400 is considered appropriate. Based on this correlation and the Cu design line recommended, EU = 8000 + 6000z kPa, where z = 0 at 2.00m AOD and this in the area covered by boreholes BH03, BH04 and BH05.

The material encountered in BH01 and BH02 is considered to be highly compressible and appropriate stiffness values cannot be derived from the ground investigation data.

The drained stiffness (E') of the cohesive deposits can be estimated from the relationship E' = Eu x 0.6 (Tomlinson, 2001). The Poisson's Ratio for clay is typically between 0.3 (drained) and 0.5 (undrained), with a value of 0.3 recommended for the silt.

5.1.4.7 Permeability

One variable head permeability test was carried out in BH01 at a depth of 3.00m (casing at 2.00m). Groundwater formed within the prepared test section to a depth of 2.25m bgl. The water within the borehole was topped up to a depth of 1.70m bgl. After the period of 30 minutes no fall in the of water was recorded and the test was abandoned. Conventional permeability ranges are not applicable for the alluvium due to the varied nature of the material.

DRAFT

5.1.4.8 Earth Pressure Coefficient, Ko

The earth pressure coefficient at rest (Ko) for superficial and normally consolidated deposits is derived from Jaky's correlation, Ko = 1-sinϕ, providing a Ko value of 0.56 for the cohesive deposits and 0.44 for the granular material.

5.1.5 Mercia Mudstone Group

The top of the Mercia Mudstone Group (MMG) was encountered between depths of 9.00mbgl and 14.70mbgl (-7.02m AOD and -12.45m AOD approximately), where it was initially encountered through window sampling as reddish brown clay with occasional mudstone lithorelics and extremely weak thinly laminated reddish brown mudstone.

The boreholes were progressed by rotary coring methods within the bedrock to a maximum depth of 20.0m bgl. The bedrock is described as weak to extremely weak mudstone and siltstone with gypsum veins.

The MMG was encountered as weathering Grades I and II in exploratory holes BH01, BH02 and BH05. Grade III was encountered in BH03 and BH04 at the top of the MMG, the MMG weathering grade transitioned into Grade II towards the base of these boreholes CIRIA C570.

5.1.5.1 Standard Penetration Test

Three SPTs were carried out in the weathered MMG, with corrected N_{60} values ranging from 19 to 49 and refusing at approximately 15.5m bgl.

Only two Atterberg Limit tests were completed on cohesive samples recovered from the MMG at depths of 10.50m (BH03) and 12.50m. The results of these tests classify the material as a low/intermediate plasticity clay, as expected based on log descriptions of *'extremely weak mudstone recovered as a gravelly silty clay'*.

DRAFT

5.1.5.2 Unconfined compressive Strength

The MMG bedrock has been described in the borehole logs as extremely weak to weak. Table 5-6 presents descriptive terms and strength values for rock as indicated in BS5930:2015 Code of Practice for site investigations. The strength description of extremely weak to weak indicates an unconfined compressive strength (UCS) of 0.6MPa to 25MPa.

Descriptive Term	Unconfined Compressive Strength (UCS,MN/m²)
Extremley Weak	0.6 to 1.0
Very weak	1.0 to 5
Weak	5 to 25
Medium Strong	25 to 50
Strong	50 to 100
Very Strong	100 to 250
Extremely Strong	>250

Table 5-5: Strength classification for Rock (BS5930:2015)

Fifteen laboratory UCS tests were carried out and the results indicate UCS values of 6MPa to 28MPa, with an average UCS value of 13MPa, which is weak according to the values presented in Table 5-6. The UCS results correlate with the log descriptions.

Point load testing was carried out on ten samples of the MMG ad $IS_{(50)}$ values ranged from 0.08MN/m² to 0.68MN/m^2.

An approximate UCS value is obtained by multiplying the Point Load Index (Is(50)) by a factor of 22. This provides UCS values ranging from 2MPa to 15MPa and these results corroborate the UCS laboratory test results. The higher Is(50) values of 0.68MN/m2 (UCS = 15MPA) correspond to layers of siltstone within the MMG.

5.1.5.3 Shear Strength

No triaxial tests were carried out on the MMG samples.

The exploratory hole logs describe the cohesive MMG as extremely weak mudstone. SPT 'N_{60}' values can be used to derive shear strength values in cohesive soils adopting a multiplying factor of 4.5 for clay (for overconsolidated clays as suggested by stroud, 1975 & CIRIA, 570); SPT 'N_{60}' values of 19 to 49 idndicates CU values raging from 85kPa to 220kPa, which equates to high to very high strength clay.

Plasticity indices within the cohesive MMG range between 10% and 15%, corresponding to a contant volume angle of friction of 27 to 30 degrees based on Table 2 of BS8002:2015. A

conservative value of 27 degrees for the constant angle of friction with an apparent cohesion (c') of 0 is recommended for design purposes.

5.1.5.4 Stiffness

The undrained stiffness (Eu) of a cohesive soil can be derived from the strength (Cu) (Jamiolkowski et al.1979). Based on the plasticity index values (15% maximum), an Eu/Cu value of 400 is considered appropriate for a Cu value range of 85kPa to 220kPa; based on this correlation the Eu value ranges from 30MPa to 135MPa.

The drained stiffness (E') of overconsolidated cohesive deposits such as the TPSF of the Mercia Mudstone Group can be estimated from the relationship E' = Eu x 0.6 (Tomlinson,2001), indicating E' values ranging from 34MPa to 88MPa.

The Poisson's Ratio for stiff clays and weathered rock is typically between 0.1 and 0.3.

5.1.5.5 Permeability

Permeability testing was not carried out during the GI. Therefore, reference has been made to published information. CIRIA C570 (Chandler RJ, 2001) states a typical permeability of the MMG of weathering Grade I to II is approximately 1.0 x 10-7. More highly weathered grades , like that initially encountered on site, are likely to become less permeable as the rock softens and fissures close, so a permeability value for the weathering grades III and IV could be much lower.

5.1.5.6 Earth Pressure Coefficient, K0

For over consolidated deposits, such as the MMG design Ko values can vary from 0.5 to 2.0 depending on the grade of weathering (CIRIA 570).

DRAFT

5.1.6 Groundwater

Groundwater monitoring installations were installed in Boreholes BH01, BH02, BH03 and BH05 within the made ground and alluvium only. Only three monitoring visits have been recorded to date and the results are summarised in Table 5-7.

Exploratory Hole (GL-mAOD)	Geology	Groundwater depth (mbgl)	Response Zone (m bgl)
BH01 1.98	Made Ground	0.97 – 1.02	1.00 – 13.00
BH02 2.25	Alluvium	1.42 – 1.63	2.00 – 5.00
BH03 1.10	Alluvium	0.51 – 0.69	1.00 – 13.00
BH05 2.07	Alluvium	1.12 – 1.19	1.50 – 11.00

Table 5-6: Groundwater Monitoring Summary – (made ground and alluvium)

Groundwater inflows were encountered in the MMG in all boreholes, the records of which are summarised in Tabel 5-8 in the absence of specific monitoring data.

Exploratory Hole (GL-mAOD)	Geology	Groundwater inflow depth (m bgl)	Rose to after 20 minutes depth (m AOD)
BH01 1.98	MMG	17.00	- 15.02
BH02 2.25	MMG	17.00	- 14.05
BH03 1.10	MMG	12.00	2.10
BH04 2.00	MMG	12.50	-8.90
BH05 2.07	MMG	17.00	-13.03

Table 5-7: Groundwater Inflow Summary of the MMG

Water monitoring results indicate groundwater was encountered between 0.51 – 1.63m bgl. However, it should be noted that in the absence of seasonal groundwater monitoring, conservative groundwater levels should be used for design purposes since the sites are located in a low lying area.

DRAFT

5.1.7 Ground Gas

The monitoring installation in BH01, BH02, BH03 and BH05 also allowed the measurement of ground gas concentrations. Only three monitoring visits have been recorded to date.

The concentrations of oxygen (O_2), carbon dioxide (CO_2) and methane (CH4) are presented in Table 5-9.

Borehole	Methane		Carbon Dioxide		Oxygen		Carbon Monoxide	
	Highest recorded concentration % v/v (Steady)	Lowest recorded concentration % v/v (Steady)	Highest recorded concentration % v/v (Steady)	Lowest recorded concentration % v/v (Steady)	Highest recorded concentration % v/v (Steady)	Lowest recorded concentration % v/v (Steady)	Highest recorded concentration % v/v (Steady)	Lowest recorded concentration % v/v (Steady)
BH01	0.4	-	0.7	0.2	20.6	19.9	4	1
BH02	***17.1**	0.3	10.7	0.1	20.2	8.8	2	1
BH03	-	-	1.5	0.1	3.1	20.7	1	-
BH05	0.1	-	2.4	1.7	20.3	0.4	2	1

Table 5-8: Ground gas Summary (> than the % LEL.)*

High concentrations of 17.1% (v/v) methane were recorded in BH02 on 12/05/21, with subsequent high carbon dioxide 10.7% and low oxygen levels 8.8% recorded in this visit. A methane concentration of 17% is above the Lower Explosive and Upper Explosive Limits. The previous site visits recorded levels below the LEL.

The concentrations of hydrogen sulphide were recorded as 1.0ppm or less in all boreholes.

Potential sources of ground gas present onsite and within the surrounding area include the natural occurring peat and organic soils, made ground and decommissioned filter tanks within the existing Crowle Sewage Treatment works. It is recommended that a ground gas monitoring programme is designed with increased timescales for monitoring; this will provide better confidence in the data collected and established the gas protection measures required on site.

5.1.8 Ground Model

The ground conditions encountered on site and recorded in the exploratory hole logs are generally as expected from the published data. A summary of the ground conditions encountered along the extend of the rising main is presented below in Tables 5-10 and Table 5-11.

Stratum	Description	Top of Stratum		Base of Stratum		Thickness (m)
		Depth (mbgl)	Elevation (mAOD)	Depth (mbgl)	Elevation (mAOD)	
Made Ground	-	0.00	1.98 – 2.25	1.50	0.75 – 0.48	1.50
Concrete	Concrete	1.50	0.75 – 0.48	1.80	0.18 – 0.45	0.30
Alluvium	Clay, silt, peat, peaty silt and sand	1.80	0.18 – 0.45	9.00 – 14.70	-7.02 – -12.45	7.20 – 10.65
Mercia Mudstone Group	Slightly gravelly silty clay and Extremley weak mudstone	9.00 – 14.70	-7.02 – -12.45	Not Proven	Not Proven	Not Proven

Table 5-9: Ground Model for the rising main section within the STW Works.

Stratum	Description	Top of Stratum		Base of Stratum		Thickness (m)
		Depth (mbgl)	Elevation (mAOD)	Depth (mbgl)	Elevation (mAOD)	
Topsoil	-	0.00	1.10 - 2.07	0.10	1.00 – 1.97	0.10
Alluvium	Clay, silt, peat, peaty silt and sand	0.10	1.00 – 1.97	10.00 – 12.00	-7.99 – -10.90	9.90 – 11.90
Mercia Mudstone Group	Slightly gravelly silty clay and Extremley weak mudstone	10.00 – 12.00	-7.99 – -10.90	Not Proven	Not Proven	Not Proven

Table 5-10: Ground model for the extent of the rising main within the fields off Windsor Crescent and adjacent to the STW treatment works.

DRAFT

5.2 Crowle STW

5.2.1 General

The generalised succession of deposits encountered in the exploratory holes is summarised as follows:

- Topsoil
- Alluvium

Interpreted geological profile sections have been included in Appendix A.

The ground investigation to inform the proposed repalacement/renewal and expansion of the existing Crowle STW treatment works was designed and prepared by [redacted]

Exploratory holes for this ground investigation have been labelled with [redacted] to differentiate between the two ground investigation sites.

5.2.2 Topsoil

Topsoil was encountered in all exploratory holes to a maximum depth of 0.30m andl generally comprised soft, brown, slightly sandy clay with frequent rootlets.

5.2.3 Alluvium

Alluvial deposits were encountered in each of the exploratory holes, between 0.10m bgl and a maximum depth of 10.00m bgl, the depth at which the boreholes terminated. The alluvial material encountered varies in composition over a short distance but comprises significant peat and organic soils.

The peat was encountered with maximum thickness of 6.20m in BH01PF. In TP01PF the peat was not fully penetrated at the termination depth of the trial pit (3.70m bgl).

Crowle STW and the surrounding agricultural fields lie within the Goole river channels (C G Godwin, 1994), prior to the diversion and drainage of the Isle of Axholme. Alluvium in this area is reported to be up to 20m thick and consists of sand, silt, clay and organic soils.

5.2.3.1 Bulk Density

In the absence of any directly obtained laboratory test results, Table 5-1 presents typical values as indicated in BS8002:2015 Code of Practice for Earth Retaining Structures.

Conservative values of 16kN/m³ should be adopted for the moist and saturated bulk density for the cohesive deposits in the alluvium. With 16kN/m³ adopted for the moist and 18kN/m³ for the saturated bulk density for the granular deposits.

DRAFT

5.2.3.2 Particle Size Distribution (PSD)

Twenty PSD tests by wet sieving and sedimentation methods were undertaken on the alluvial deposits. The component proportions of the cohesive and granular materials are summarised in Table 5-14.

Stratum	Range of Particle Sizes (%)			
	Clay	Silt	Sand	Gravel
Alluvium	17 - 36	37 - 69	8 - 20	5

Table 5-11: Summary of PSD test results for the cohesive alluvium

Stratum	Range of Particle Sizes (%)			
	Clay	Silt	Sand	Gravel
Alluvium	1 - 22	5 - 71	17 - 92	5

Table 5-12: *Summary of PSD test results for the granular alluvium*

5.2.3.3 Atterber Limits / Plasticity

Nineteen tests were completed on the apparent cohesive samples recovered from all boreholes and trial pits, recovered from depths between 1.50m bgl and 8.50m bgl. The results of these tests are summarized in Table 5-14 and Table 5-15.

Parameter	Range
Moisture Content (%)	120 -310
Liquid Limit (%)	150 - 300
Plastic Limit (%)	-
Plasticity Index (%)	-

Table 5-13: Summary of Plasticity test results of organic soils

Parameter	Range
Moisture Content (%)	120 - 200
Liquid Limit (%)	84 - 190
Plastic Limit (%)	46 - 111
Plasticity Index (%)	38 - 91

Table 5-14: Summary of Plasticity test results (cohesive soils)

The material classifies as extremely high plasticity silt, with six samples classified as non plastic and Liquid Limits in the high percentages as shown in Figure 5-3.

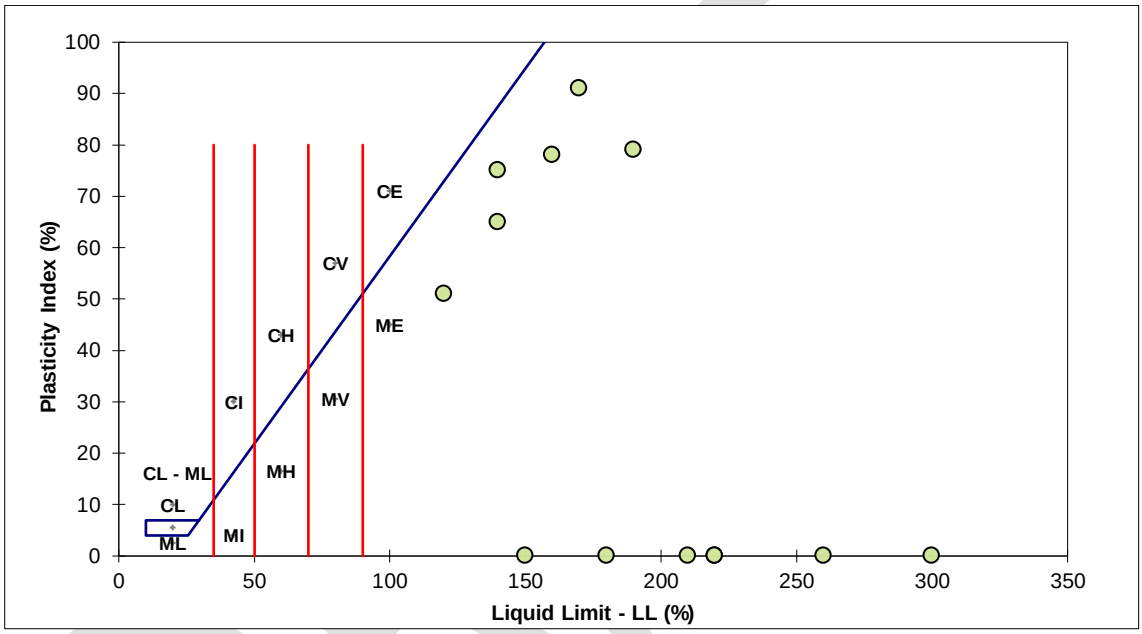


Figure 5-4: Plots of Plasticity Index against Liquid Limit for alluvium

5.2.3.4 Standard Penetration Tests (SPTs)

Fifty SPTs were carried out in all alluvial strata identified in all boreholes, at depths between 1.20m and 10.00m bgl, with 'N_{60}' values raging from 1 to 27. The variation of the SPT values of these deposits with depth is indicated by the SPT vs depth plot shown in Figure 5-4.

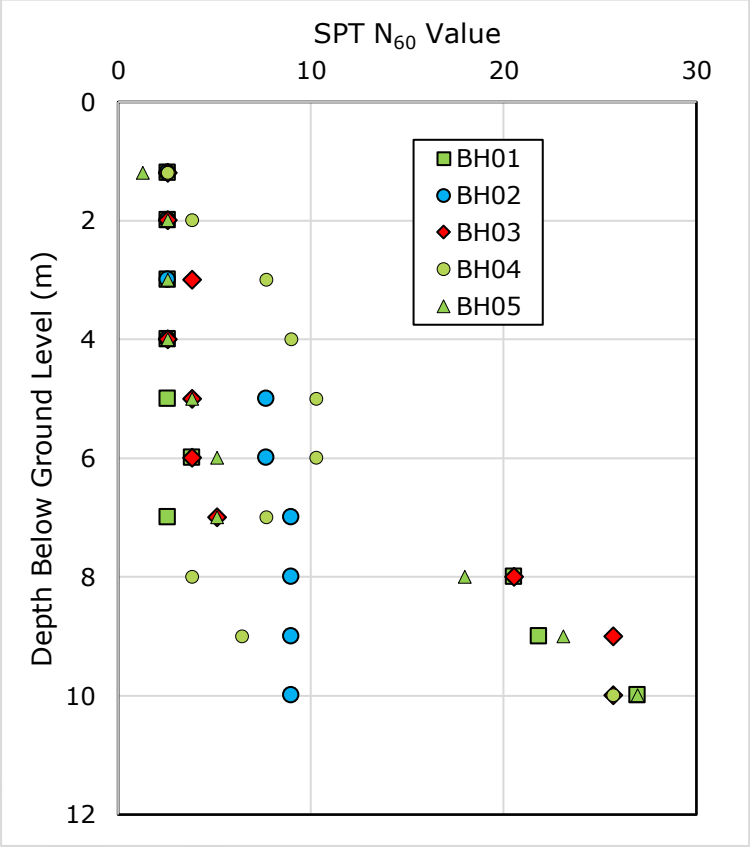


Figure 5-5: SPT N_{60} values in Alluvium

**N values corrected for hammer efficiency only, not corrected for overburden*

The SPTs carried out within the highly compressible soils (including peat) recorded SPT 'N_{60}' values ranging from 2 to 7 at depths between 1.20m and 10.00m bgl. Higher SPT results were encountered in BH01PF, BH03PF and BH05PF below 8.00m bgl, these results were carried out in medium-dense sand.

5.2.3.5 Shear Strength & Stiffness

No triaxial tests were carried out on the alluvium samples.

18 SPT tests were carried out in the alluvial deposits, with 'N_{60}' values recorded between 2 and 10, all other SPTs were carried out in granular (non plastic) material encountered in the alluvium. The exploratory hole logs describe the alluvium material as very soft to soft consistency and medium-dense sand towards the base of the borehole.

The deposits encountered are highly organic with considerable layers of highly compressible peat, this material is likely to undergo secondary consolidation under self weight. Therefore, conventional correlations and parameters are not suitable for these deposits.

5.2.3.6 Earth Pressure Coefficient, Ko

The earth pressure coefficient at rest (Ko) for superficial and normally consolidated deposits is derived from Jaky's correlation, K0 = 1-sinϕ, providing a Ko value of 0.56 for the cohesive deposits and 0.44 for the granular material.

5.2.4 Ground Model

The ground conditions encountered on site and recorded in the exploratory hole logs are as expected from the published data. A summary of the ground conditions encountered is presented below in Table 5-16.

Stratum	Description	Top of Stratum		Base of Stratum		Thickness (m)
		Depth (mbgl)	Elevation (mAOD)	Depth (mbgl)	Elevation (mAOD)	
Topsoil	Soft slightly sandy clay with frequent rootlets	0.00	0.86 – 1.07	0.10 - 0.30	0.56 – 0.84	0.10 – 0.30
Alluvium	Clay, silt, peat, peaty silt and sand	0.10 – 0.30	0.56 – 0.84	10.00	- 8.93 – -9.14	9.90 – 9.70

Table 5-15: Ground model for STW Treatment Works Replacement.

DRAFT

6 Geotechnical Design Parameters

6.1 Rising Main

Based on the ground investigation, including in-situ and laboratory test results and correlations commonly used for geotechnical design, as described above, the following characteristic geotechnical parameters are considered appropriate for the design .

Parameters	Alluvium		Mercia Mudstone Group	
	Cohesive	Granular	Weathered	Bedrock
Weight/Density				
γ_{bulk} (kN/m³)	18	18	19	25
γ_{sat} (kN/m³)	18	20	19	25
Poisson Ratio				
V	0.5	0.3	0.2	0.1 – 0.3
SPT				
N	1 - 23	8 - 36	19 – 49*	-
Undrained Shear Strength				
C_u (kPa)	Cu = 20 +15z kPa, where z = 0 at 2.00m AOD.	-	85kPa – 220kPa	-
Drained Shear Strength				
c' (kPa)	0	-	0	-
Φ' (^{0})	18	34	27	34
Unconfined Compressive Strength				
UCS (MPa)				6 - 28
Stiffness Parameters				
Eu (MPa)	Eu = 8000 + 6000z kPa, where z = 0 at 2.00m AOD.	-	34 - 88	
E' (MPa)	E' = Eu x 0.6	13	E' = Eu x 0.6	200 - >1000
Earth Pressure Coefficient				
K_0	0.56	0.44	0.5 – 2.0	0.5 – 2.0

Table 6-1: Summary of Geotechnical Parameters for – Rising main

*Weathered bedrock

6.2 Crowle STW

Based on the ground investigation, including in-situ and laboratory test results and correlations commonly used for geotechnical design, as described above, the following characteristic geotechnical parameters are considered appropriate for the design .

Parameters	Alluvium	
	Cohesive*	Granular
Weight/Density		
γ_{bulk} (kN/m³)	16	16
γ_{sat} (kN/m³)	16	18
Poisson Ratio		
V	0.5	0.3
SPT		
N	2 - 10	1 - 27
Undrained Shear Strength		
C_u (kPa)	*	-
Drained Shear Strength		
c' (kPa)	0	-
Φ' (^{0})	N/A	32
Stiffness Parameters		
Eu (MPa)	*	-
E' (MPa)	*	10
Earth Pressure Coefficient		
K_0	0.56	0.44

Table 6-2: Summary of Geotechnical Parameters for Crowle STW

*NOTE: The material is highly compressible and is likely to undergo secondary consolidation when loaded and consolidation under selfweight.

DRAFT

6.3 Ground Chemistry and Buried Concrete Classification

Chemical testing carried out on recovered samples of all strata encountered revealed pH values ranging from 6.5 to 8.7 and water-soluble sulphate values ranging from <97mg/l to 3500 mg/l.

In accordance with Table C2 of BRE Special Digest 1 (SD1): 2005 Concrete in Aggressive Ground, a Design Sulphate Class of DS-3 and an Aggressive Chemical Environment Class (ACEC) of AC-3 is recommended for the site. However, *Box C8 Practical notes on pyritic ground* estates that concrete in pyritic ground which is initially low in soluble sulfate does not have to be designed to withstand a high potential sulfate class unless it is exposed to ground which has been disturbed* to the extend that contained pyrite might oxidise and the resultant sulfate ions reach the concrete.

Therefore, it is concluded that a Design Sulphate Class of DS-3 and an Aggressive Chemical Environment Class (ACEC) of AC-3 is suitable for the site.

The design of buried concrete should take into account the above ACEC rating.

***Disturbed ground:** *natural ground that is substantially disturbed; for example, by cutting and filling to terrace a site, or by excavation and backfilling, so that air can enter and oxidise any pyrite contained therein. Simply curring through the ground without opening up the ground beyond the cut face (eg piling operations or exacavation without backfill) does not generally result in disturbed ground.*

DRAFT

7 GEOTECHNICAL RISKS

A Geotechnical Risk Register or Designer's Risk Register with geotechnical risks identified should be developed prior to design to identify the potential risks to the proposed development. This will include mitigating measures to deal with the identified geotechnical risks to infrastructure and site personnel.

The potential geotechnical hazards identified from the ground investigation at the at the site are shown below:

- Ground conditions are likely to vary over the STW site and the length of the rising main with areas of soft highly compressible soil present. Differential settlement due to these variations is likely to occur.
- A considerable depth of highly compressible ground is present at the STW site.
- The sides of excavations within the alluvium are likely to collapse unless suitable support is provided or the sides are battered to a suitable angle.
- Unproven depth of MMG (bedrock) at the Crowle STW Treatment Works Infrastructure Replacement site reduces the confidence for detail design as the superficial soils are not suitable to support foundations.
- Silts, sands and gravels will flow into excavations taken below groundwater level unless suitable techniques are adopted to support and dewater the excavation.
- Changes in groundwater level over the seasons or perched water conditions within the alluvium may induce settlement or heave.
- Obstructions in the made ground which could interfere with the excavations at the existing Crowle STW.

DRAFT

8 CONCLUSIONS

8.1 General Site Conditions

The nature of the materials on-site and the investigation methods used (cable percussion boring and window-sampling) preclude direct measurement of most geotechnical design parameters. These parameters have, therefore, been derived from the results of penetration testing, the descriptions on the logs and published literature and guidelines.

8.1.1 Crowle STW – Rising Main Replacement

It is anticipated that the ground conditions likely to be encountered will consist mostly of peat ,sand and organic soils overlying the Weathered Mercia Mudstone (MMG). The depth of the MMG weathering varies greatly, therefore, ground conditions are likely to vary with depth from firm to stiff clay to intact mudstone, siltstone and occasional gypsum.

Groundwater and possible sub-artesian water was encountered in all boreholes; therefore dewatering measures are likely to be needed.

A Design Sulphate Class of DS-3 and an Aggressive Chemical Environment Class (ACEC) of AC-3 is considered to be appropriate for the design of buried concrete at the site.

8.1.2 Crowle STW Treatment Works Infrastructure Replacement

The ground conditions for the site predominantly comprised very soft to soft peat, organic soils and medium dense sand.

It is recommended that foundations for new structures are taken through the Alluvium to bear on to the clay and mudstone of the Mercia Mudstone Group. The depth of the MMG at this site location was not proven, however, the depth of the MMG can be anticipated based on boreholes carried within the Crowle Sewage Treatment works adjacent to the site (Rising Main Replacement GI BH01 and BH02), these boreholes encounterd the bedrock at levels of -7.02m and -12.47m AOD.

Furthermore, the thickness of the Alluvium deposits can vary greatly in this area according to the literature. Ground conditions are likely to vary with depth from, very soft to soft peat and organic soils, to medium dense sand.

A Design Sulphate Class of DS-3 and an Aggressive Chemical Environment Class (ACEC) of AC-3 is considered to be appropriate for the design of buried concrete at the site.

DRAFT

9 REFERENCES

1 British Standard Institute (BS) EN 1997-2:2007 Incorporating corrigendum June 2010 – Eurocode 7: Geotechnical Design – Part 2: Ground Investigation and Testing.

2 British Geological Survey (BGS) 1:50,000 Scale Digital Geological Mapping, 2020.

3 Building Research Establishment (BRE) Special Digest 1 (SD1): 2005: concrete in the aggressive ground.

4 Foundation Design & Construction, 7th Edition, M J Tomlinson, 2001.

C G Godwin, E. G. (1994). Geology of the country around Goole, Doncaster and the Isle of Axholme, Memoir for one-inch sheets 79 and 88. *British Geological Survey*, 124.

Chandler RJ, F. A. (2001). *Engineering in Mercia Mudstone.* London: CIRIA.

CIRIA. (2004). *Engineering in the Lambeth Group .* London : CIRIA.

McEVoy, F. (2018). *Regional geological summaries - South-West England Region.* Nottingham: BGS.

P R N Hobbs, J. R. (2002). *Engineering Geology of British Rocks and Soils - Mudstones of the Mercia Mudstone Group.* Keyworth, Nottingham: British Geological Survey.

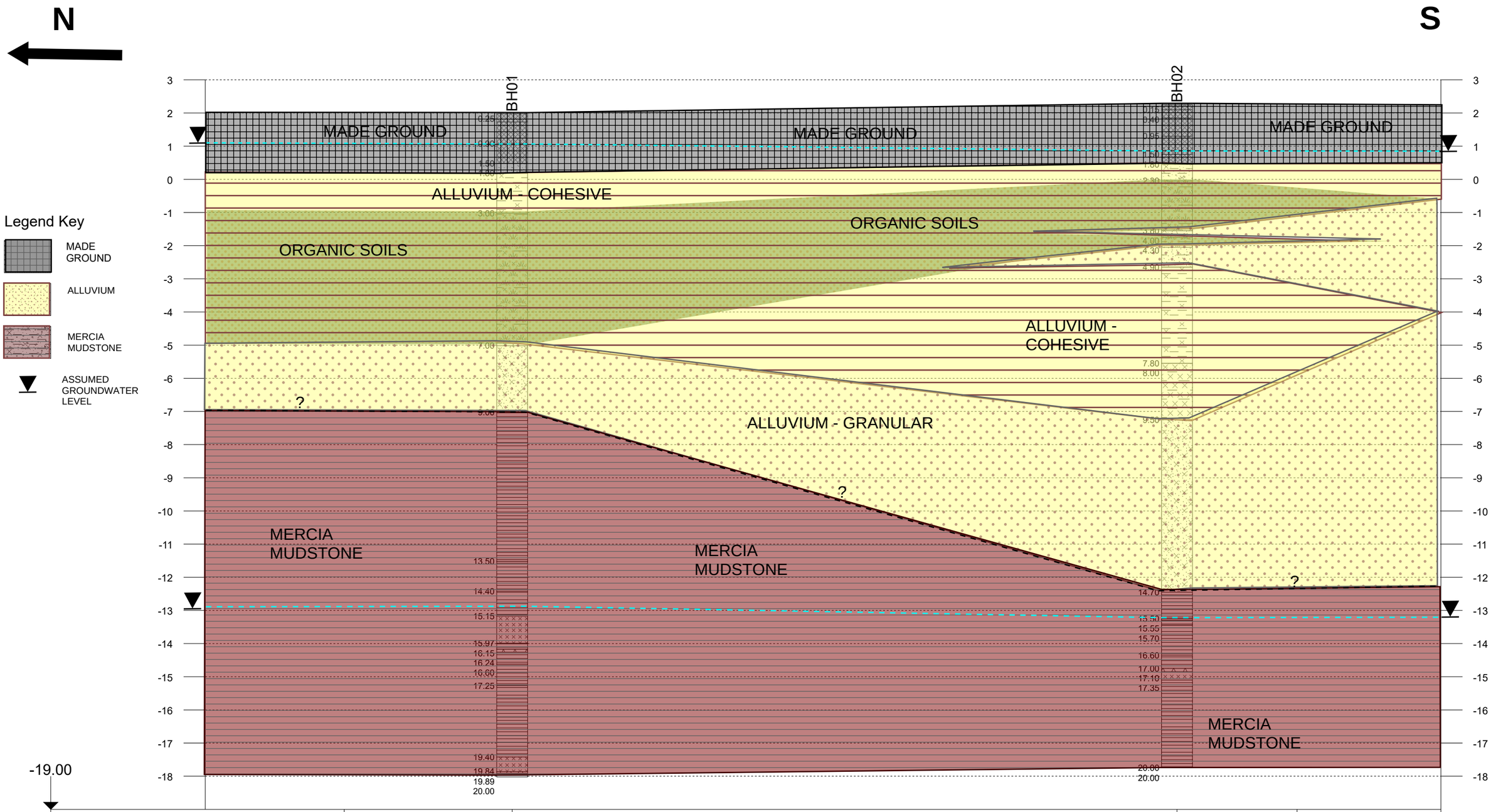
Williams, E. E. (1985). Geology of the country around Taunton and the Quantock Hills. *Memoir for 1:50000 geological sheet 295, New series*, 49.

DRAFT

Appendix A: Drawings

Project Id: A131380-026-	Title: Section line 1
Project Title: Crowle STW- Infra	Vertical Scale: 1:116
Location: Crowle STW Treatment works	Horizontal Scale: 1:135
Client: STW	Engineer: [redacted]

COWI



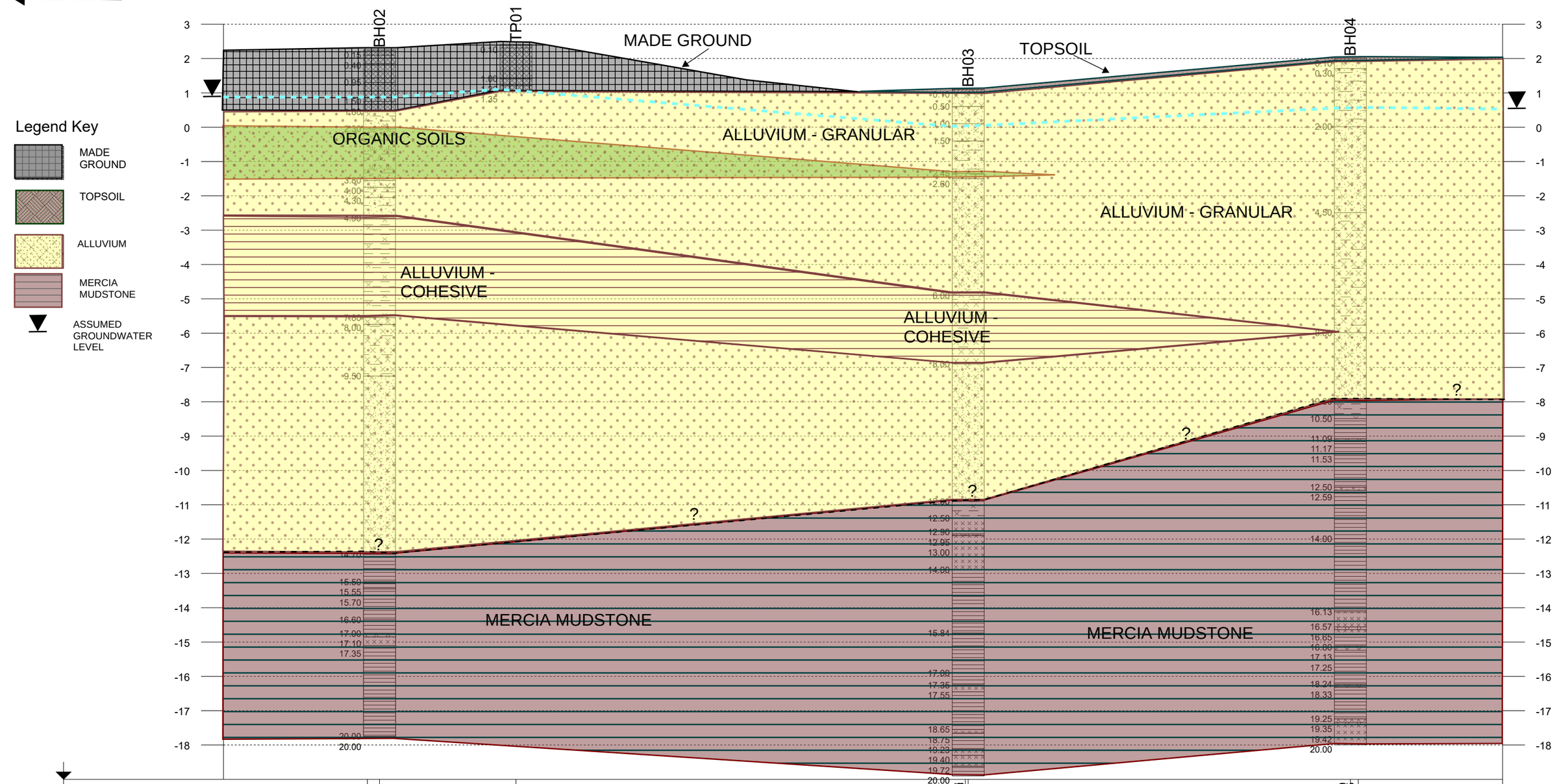
Chainage (m)	0.00	5.89	29.22	33.44	
Offset (m)	0.24		0.37		
Elevation (mAOD)	1.98		2.25		

Project Id: A131380-026-	Title: Section line 1
Project Title: Crowle STW- Infra	Vertical Scale: 1:116
Location: Crowle STW Treatment works	Horizontal Scale: 1:1347
Client: STW	Engineer: [redacted]

COWI

NW

SE



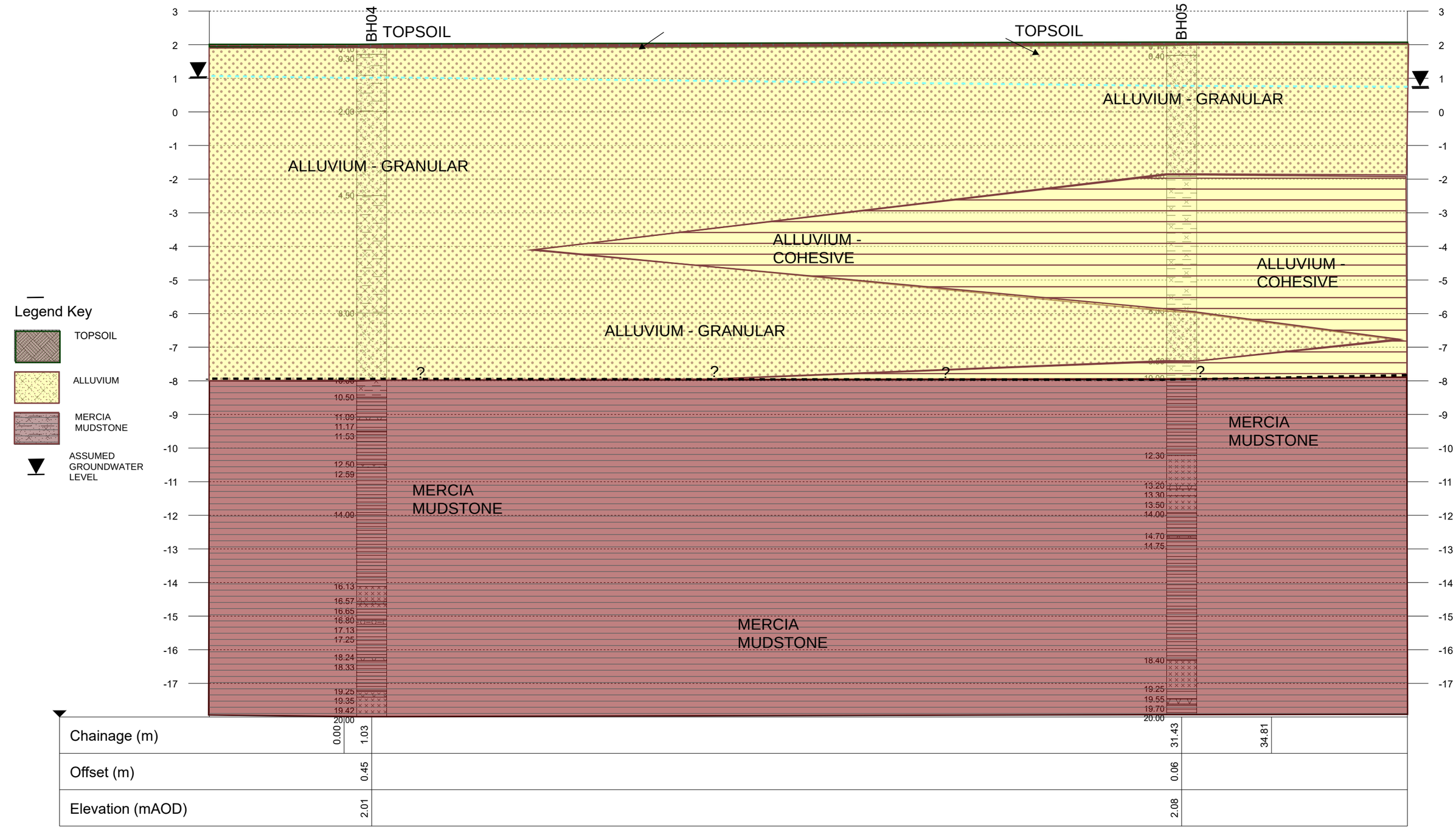
| | | |

Project Id: A131380-026-	Title: Section line 1
Project Title: Crowle STW- Infra	Vertical Scale: 1:111
Location: Crowle STW Treatment works	Horizontal Scale: 1:140
Client: STW	Engineer: [redacted]

COWI

N

S



Legend Key

- TOPSOIL
- ALLUVIUM
- MERCIA MUDSTONE
- ASSUMED GROUNDWATER LEVEL

| | | |

Project Id: A131380-026	Title: Section line 1
Project Title: Crowle STW - Renewal	Vertical Scale: 1:64
Location: Crowle STW	Horizontal Scale: 1:683
Client: STW	Engineer: [redacted]

COWI

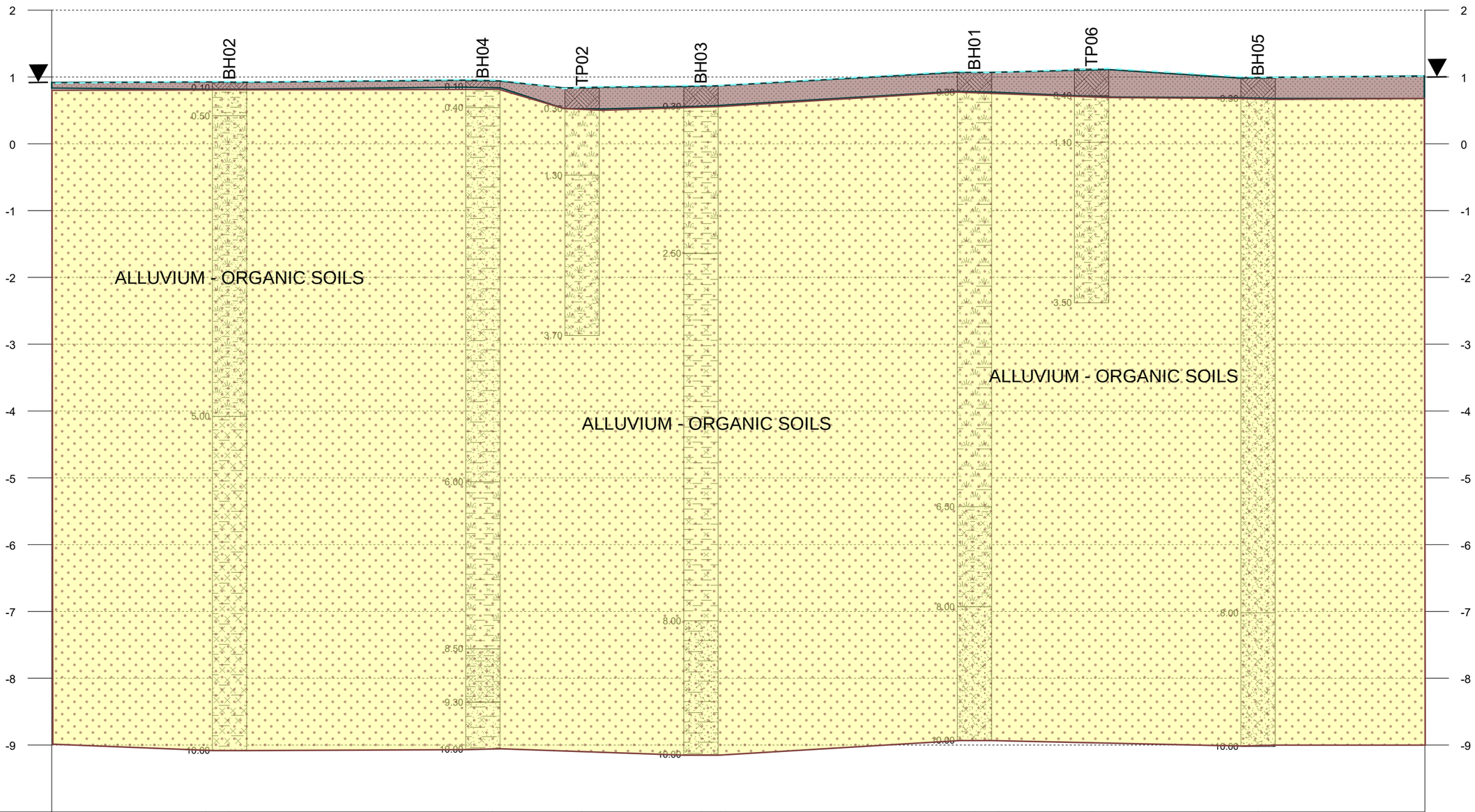
N

S

CROSS SECTION - CROWLE STW

Legend Key

- TOPSOIL
- ALLUVIUM - PEAT & ORGANIC SOILS
- ASSUMED GROUNDWATER LEVEL



-10.00

| | | |

Appendix B: Ground Investigation Factual Report